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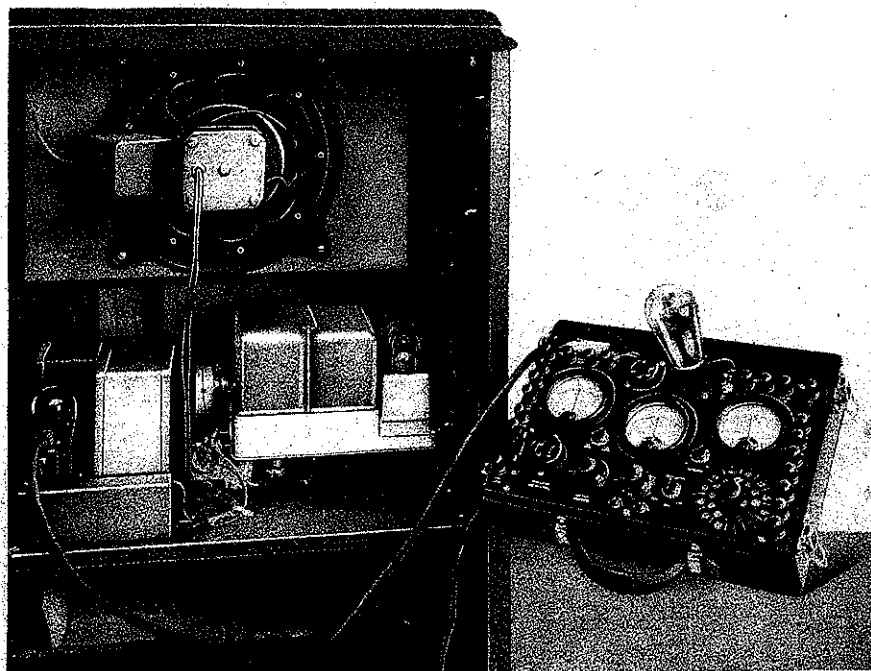


Technical Lesson 39

INSTRUMENTS USED IN SERVICING RADIO RECEIVERS

A very good point always to keep in mind in radio service work is that the circuits of all receivers may be divided into four main sections, namely, (1) the radio-frequency amplifier or tuning circuits which select and amplify the desired signal, (2) the detector which separates the a-f component from the r-f component of an incoming signal, (3) the audio-frequency amplifier which receives the a-f component as it comes from the detector and builds up the audio frequencies until they are sufficiently strengthened to operate the loudspeaker satisfactorily, and (4) the power supply system. If, when servicing a troublesome set, you come to the conclusion that the cause of faulty operation is due to some sort of trouble in the receiver itself then the difficulty must lie in one of the circuits we have just mentioned. Knowing this to be the case we can map out a logical way of approaching our work in radio trouble shooting. Our aim now is to separate the four main sections according to a plan that will enable us to prove whether or not each section is performing as it should, and then if one section is found to be at fault we can concentrate on the wiring and parts associated with that particular section until we have corrected the trouble.

So then, if you fully understand our purpose in considering the main circuits of a receiver by sections and treating each one as a separate unit, we will proceed to the first part of this lesson wherein we deal with the principles relating to the use of a standard set tester or analyzer. A series of explanations will be given to cover the principles of testing circuits through the



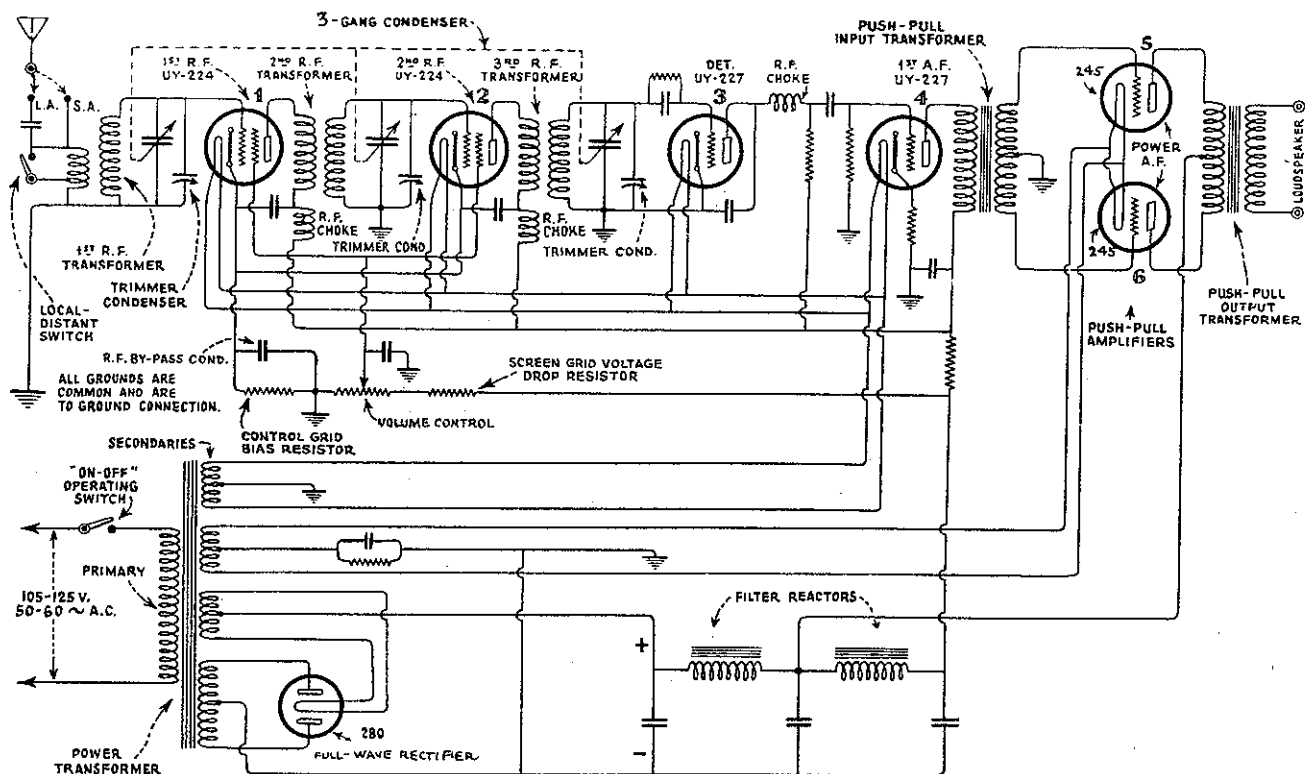


Figure 2

sockets of a receiver and each explanation will be centered around a certain section of a typical receiving circuit. The photograph in Figure 1 shows a standard set tester being used to take various voltage and current readings at the sockets of a receiver. When you finish studying this part of the lesson you will understand how and why these tests are performed. From your previous work on this subject you know that when a test set-up is used like the one shown in the photograph, the tester plug must be inserted in the desired socket of the receiver and the tube which normally operates in this socket must be inserted in the set tester socket. These represent the conditions under which our series of explanations are made. For a typical receiving circuit on which to base our series of explanations we have selected a screen-grid receiver that operates from an a-c power line, the complete schematic diagram of the receiver being shown in Figure 2.

A brief description of the receiver diagram in Figure 2 is as follows: The receiver consists of two stages of radio-frequency amplification having in all three tuned r-f circuits. Each radio-frequency stage employs a 222 type screen-grid tube. The detector uses a 227 tube, and the stage of straight audio-frequency amplification that follows also uses a 227 tube. In the final audio-frequency stage two 245 tubes are used in push-pull and these tubes feed the loudspeaker. The filaments and heaters are energized with alternating current of the proper voltage which comes from the several secondaries of the power transformer while a high-voltage winding on this same transformer delivers its a-c output to a full-wave rectifier of the '80 type. The rectifier tube serves to change the alternating current into a pulsating direct current and the filter system smoothes out the pulsations to provide a substantially steady flow of direct current which is required for the plate circuits of the receiver. Before getting down to the actual explanation of the principles involved in tube-socket testing we will briefly outline the practical operation of a standard set tester when used under the conditions shown in Figure 1.

You can see in Figure 1 that voltage and current readings are being taken at the sockets of a receiving set. The tests would be made somewhat as follows:

- (1) To read filament or heater voltage at a tube socket the test button controlling the desired meter scale is depressed. For example, if the heater voltage of a 222 type tube is desired a button which might be marked "FIL. 4 V A-C" in certain analyzers would be used. The heater voltage of a 227 tube would be read in the same manner, that is, by using the same button and voltmeter scale.
- (2) The plate voltage of a tube may be read by depressing a button which might be marked "B VOLTS 300 V" and the indication in this instance would be observed on the 300 volt scale of the d-c voltmeter.
- (3) The plate current of a tube may be read by depressing a button which might be marked "PLATE M.A. 15 M.A." and the current reading would be noted on the milliammeter scale corresponding to the button used, or 0-15 m.a. scale. In certain analyzers the button just mentioned could be used to measure the plate current of various tubes with the exception of the 171 type and for the latter tube it would be necessary to use a higher scale, which for example, might be a scale controlled by a button marked "PLATE M.A. 150 M.A.".
- (4) The grid bias or "C" voltage of a tube may be read by depressing a button which might be marked "C VOLTS 75 V" and this would connect the 0-75 volt scale of the d-c voltmeter into the circuit.
- (5) The heater bias of a tube, for example a 222 or 227 tube, may be read by depressing a button which might be marked "CATHODE VOLTS 75 V". This button would control the corresponding scale on the d-c voltmeter.

From the description just given concerning the operation of a set tester it is easy to understand that voltage and current readings of the various tube circuits are taken by manipulating certain buttons on the tester panel which in turn cut in the desired meter scales in the circuits under test. The drawings in Figures 3, 4, 5, and 6 tell at a glance the story of just where meters would be located in the tube circuits for each test that might be taken at a tube socket.

PRINCIPLES APPLYING TO THE USE OF A SET TESTER OR ANALYZER. By examining Figures 3, 4, 5, and 6 you will see that we have cut up the receiver diagram in Figure 2, into its four main sections according to the plan previously outlined. Each section is drawn in enlarged form to allow us to clearly show the position occupied by each meter during the tests. By considering the sections separately and explaining each and every individual test you will obtain a clear picture of how circuits are checked by means of meters. Remember that only one reading can be taken at a time with a set tester equipped with only one meter, whereas, two or more readings can be taken simultaneously if more meters are provided. Now examine Figure 2 and then carefully study the principles given in Explanations Nos. 1 to 4 beginning on the next page.

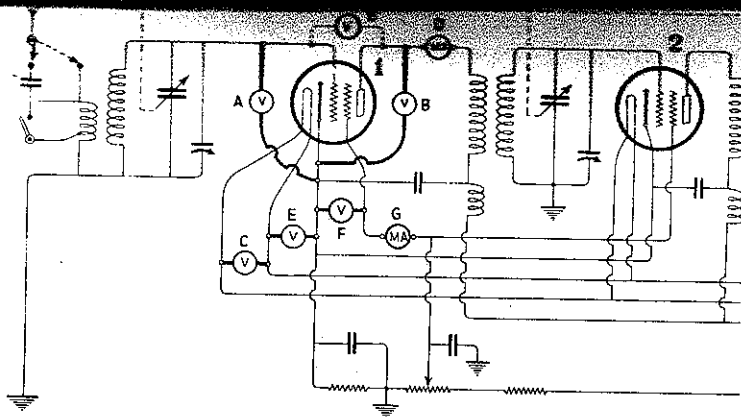


Figure 3

EXPLANATION NO. 1. Refer to Figure 3. Our first explanation concerns the location of meters at the various terminals of socket #1. This is a radio-frequency amplifier socket employing a screen-grid tube. Our illustration explains the method as actually used in practice to obtain voltage and current readings by means of a set tester as in Figure 1. The location and purpose of each meter is as follows:

- Meter in position A. This shows a d-c voltmeter connected between the control grid and cathode of the tube and it measures the biasing voltage on the grid.
- " " " B. This shows a d-c voltmeter connected between the plate and cathode of the tube and measures plate voltage.
- " " " C. This shows an a-c voltmeter connected across the two leads which supply heating current to the heater wire located within the cathode thimble, hence, the meter reads a-c heater voltage.
- " " " D. This shows a d-c milliammeter inserted in series with the plate supply and, consequently, it reads the direct current flowing in the plate circuit.
- " " " E. This shows a d-c voltmeter connected between the cathode and heater circuits of the tube and, hence, the meter reads cathode voltage.
- " " " F. This shows a d-c voltmeter connected between the screen grid and cathode and it reads the positive voltage on the screen grid. With different adjustments of the volume control this voltage will vary.
- " " " G. This shows a d-c milliammeter placed in series with the screen-grid and it measures screen-grid current.

After readings are completed at socket #1 then the same procedure would be carried out in making tests at socket #2 which also holds an r-f amplifier tube. Consequently, the meters would be placed in both circuits in the same relative positions and the explanations given above would apply in either case. If you examine the two r-f stages carefully you will find each one to be exactly alike.

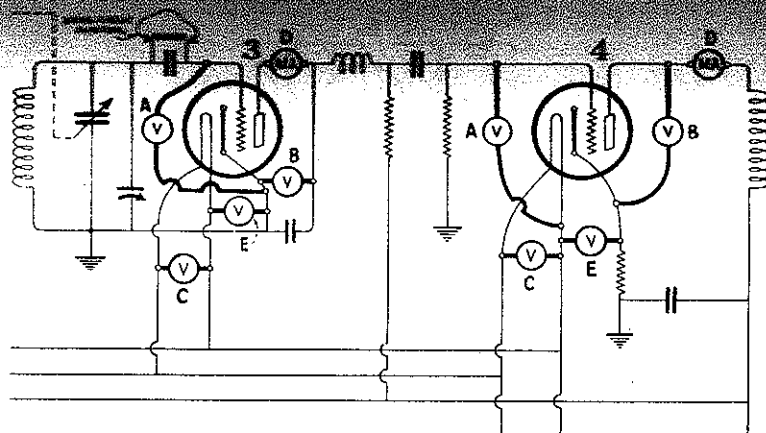


Figure 4

EXPLANATION NO. 2. Refer to Figure 4. The detector and 1st a-f amplifying stage, at sockets #3 and #4 respectively, are the circuits next to be studied. The diagram above shows three-electrode tubes in these sockets. Remember that the letters A, B, C, and so on are merely reference letters used to identify each meter on the drawing with its explanation in the text below. The meter connections at the detector socket, or socket #3, are as follows:

- | | |
|----------------------|---|
| Meter in position A. | This shows a d-c voltmeter connected between the detector grid and cathode. Only a very slight indication may be observed on a meter when connected between these two electrodes because of the presence of the high resistance grid leak which is about 1 megohm in this case. If the grid leak were shorted with a wire a more noticeable reading might be observed on the voltmeter. |
| " " B. | This shows a d-c voltmeter connected between plate and cathode and it reads the potential supplied to the plate. |
| " " C. | This shows an a-c voltmeter connected between the heater terminals and it indicates the a-c voltage supplied by one of the secondaries of the power transformer. |
| " " D. | This shows a d-c milliammeter connected in series with the plate supply and, therefore, it reads the direct current passing through the plate circuit. |
| " " E. | This shows a d-c voltmeter connected between the cathode and heater circuits and measures the voltage of the cathode with reference to the heater circuit. |

After all the readings are completed at socket #3, as outlined above, then you would proceed to make tests at socket #4. As the drawing above, in Figure 4, indicates, the meters are again connected to the different tube circuits of socket #4 for each test in the same manner as for tests at socket #3 and, consequently, these tests need not be repeated. There is one thing to mention, however, a definite biasing voltage is supplied to the grid of socket #4 according to the plate voltage used since the tube in this socket is an a-f amplifier. Remember that a definite grid bias reading is not to be expected in the case of the detector at socket #3 because it employs grid-leak detection.

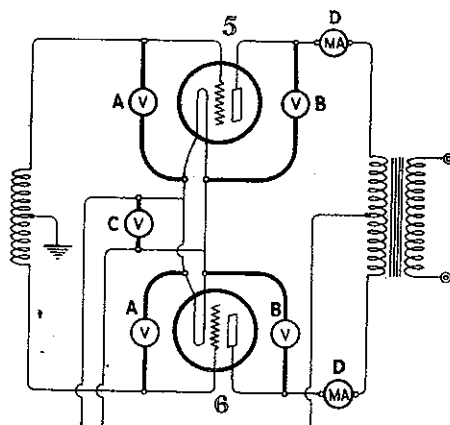


Figure 5

EXPLANATION NO. 3. Refer to Figure 5. You are now ready to make the next series of routine tests at the sockets of the push-pull amplifier. Begin at socket #5 which holds one of the 245 power tubes. Remember that to put everything in readiness for tests at socket #5 the 245 tube must be removed from this socket and inserted in the UX socket in the set tester after which the tester plug is inserted in place of the tube in socket #5. The purpose of the meters and their locations in the tube circuits are as follows:

- Meter in position A. This shows a d-c voltmeter connected between grid and filament which provides an indication of the negative grid bias supplied to this tube.
- " " " B. This shows a d-c voltmeter connected between plate and filament and the reading in volts observed on its scale tells us the value of the positive potential supplied to the plate.
- " " " C. This shows an a-c voltmeter connected across the filament and it shows the input terminal voltage which sets up a flow of current in the filament wire, and the current in turn heats the wire and causes it to emit electrons.
- " " " D. This shows a d-c milliammeter connected in series with the plate circuit and it indicates the plate current passing between the plate and filament electrodes of the tube and through the wiring and parts which comprise the plate circuit external to the tube.

The above steps complete the check-up at socket #5. Now remove the tester plug from socket #5 and also remove the 245 tube from the tester socket and replace the tube in socket #5. Having completed our test of socket #5 we will go to socket #6. To take readings at socket #6 remove the other 245 tube from this socket and insert it in the tester UX socket and then insert the tester plug in socket #6. All of the tests to be made at socket #6 are exactly similar to those given above for socket #5 since the two 245 tubes are in push-pull relation, and, therefore, you will find them to be worked under similar conditions.

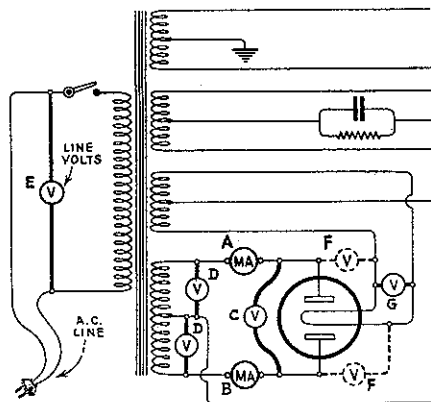


Figure 6

EXPLANATION NO. 4. Refer to Figure 6. The next set of readings to be considered are those which are taken at the rectifier socket. A study of the diagram in Figure 6 shows how meters could be connected to provide readings which might aid a serviceman in locating trouble. The readings tell us the following facts about the power unit and rectifier in the above diagram.

- Meter in position A. This shows a d-c milliammeter connected in series with one plate of a full-wave type '80 rectifier tube. This meter measures the direct current output of this particular plate circuit.
- " " " B. This shows a d-c milliammeter connected in series with the other plate of the type '80 rectifier and it measures the direct current output of the second plate circuit. The readings obtained on a milliammeter in either (A) or (B) positions should be nearly alike for a normal tube. If the readings were abnormally low it would probably mean that the electron emission of the filament was low, or possibly the a-c voltage output of the secondary which supplies these plates might be considerably less than normal. By adding the current values in each plate circuit you get the total direct current, or rectified a-c which passes first to the filter system and thence to the receiving tubes.
- " " C. This shows an a-c voltmeter connected between the two plates of the rectifier and, therefore, the meter is also connected to the extreme ends of the power transformer plate winding as you can see. Hence, the meter measures the a-c output voltage of this winding. Since the winding is tapped at its center the voltage actually on each plate is but one-half of the voltage across the full winding.
- " " D. This shows an a-c voltmeter placed between one plate and the midtap or center of the plate winding of the transformer, and the meter in this position indicates the a-c voltage generated across
- (cont'd on next page)

the turns which comprise this portion of the winding.

Meter in position E.

This shows an a-c voltmeter connected across the primary winding of the power transformer and when the power is on the receiver, as it would be during tests of this kind, the meter will also be connected across the a-c house lighting supply. At this point let us mention that in certain set testers which are equipped with lamp cord and plug arrangement you need only to insert the plug in the a-c socket and press the appropriate button to take a line voltage reading. Otherwise you would have to use test leads attached to the proper binding posts to connect the a-c voltmeter to the line supply and in this case the meter would be used as an external meter. The test described in (D) on the previous page measures the voltage on either side of the center tap of the plate supply transformer. If the construction of a set tester will not permit you to take these measurements through the tester plug and socket you could use the a-c voltmeter independently as for any external measurements, through the a-c terminal posts and test leads.

Meter in position G. Filament a-c voltmeter measures filament e.m.f.

The foregoing, Explanations 1 to 4, complete our tube-socket analysis tests of the receiver shown in Figure 2, and you should now have a clear idea of the principles concerning the use of meters in set testers, or analyzers.

Other tests which have not been mentioned heretofore but which some set analyzers afford are discussed in the next few paragraphs. A test which may be helpful in locating trouble in a receiver is shown by dotted lines at "F and F" in Figure 6, outlining the positions of meters which would be connected in the output of the rectifier when the buttons which control these meters were pressed. For this test the '80 rectifier tube would be left out of the analyzer and, hence, you would read the voltage delivered by each half of the secondary of the power transformer through the filter and voltage supply system. When you put the '80 tube back in the analyzer socket after the test just mentioned and the button is not released you may notice an increase of voltage on the a-c scale which is accounted for by the back action of the filter condensers, they being charged up to the a-c peak voltage of the transformer output and, as you know, a-c voltmeters do not read peak voltages but only working voltages. It is also well to mention if instead of working with a filament type rectifier, such as the '80 type, you were making tests on an eliminator or socket-power unit using a gaseous type rectifier, such as the Raytheon B.H., then the selected voltage button in some analyzers would permit you to read the secondary voltage of the power transformer of the eliminator or socket-power unit. Then, by putting the rectifier tube in the analyzer and pressing the button which controls the d-c milliammeter the plate current output of the tube could be measured.

Another use of a d-c voltmeter in certain types of analyzers is one in which a certain button which might be marked "Grid-to-Plate voltage" would be pressed

to tie in the meter between grid and plate of a tube as shown by the dashed lines marked "H" in Figure 3. It is important to mention that where sets with series filaments are tested, it is imperative to shut off the main power supply while shifting from one socket to another. Further, no readings at receiver tube sockets should be taken with the tube out of the tester, since it is usually necessary for the filament circuit to be intact when tests are being made. Filament voltage, plate voltage, and so on, should, therefore, be taken only with the tube in place in the analyzer and its cord and plug in the socket of the radio set. Under these conditions tests may proceed normally and the usual values taken.

The following simple tests are sometimes made to locate the faulty section that is preventing signals from passing through a receiver, that is, to determine whether the trouble is in the radio-frequency or audio-frequency side of the set. After the set is turned on and the tubes are allowed to heat if then you remove the detector tube from its socket this should cause a click to be heard in the loudspeaker, providing the a-f circuits are functioning between the detector and the speaker. If no click were heard you would look for the difficulty in the a-f circuits. On the other hand if a click were heard you would naturally look to the r-f circuits for the fault. A quick way of testing the r-f circuits is to get a modulated oscillator into action, providing this instrument is available, and set it to generate a good strong signal and then connect the pickup lead in some convenient way to the terminals on each of the stator plates of the tuning condensers in succession and listen for the indications in the loudspeaker. Or, if you were using an output meter when testing you would get the indications on the meter. It is suggested that you first connect the pickup lead on the stator terminal of the tuning condenser in the r-f stage ahead of the detector. You will see that the signal is being delivered directly to the input of the detector and r-f stages between the antenna circuit and the stage you are testing are not now called upon to do any work. If you get a fairly strong signal through it proves that the difficulty rests somewhere in the r-f stages not used. Suppose this is not the case, however, and you have thus far failed to bring in a signal, then the procedure would be to connect the pickup lead to the stator of each tuning condenser in succession working from the r-f stage ahead of the detector toward the antenna input or toward the 1st r-f stage of the receiver. With a receiver in good operating condition and carefully tuned to the oscillator's frequency or to a broadcast station the signal should increase in strength when each succeeding stage of r-f amplification is cut in, hence, if the signal comes through when testing at one position but not in some other you will know in what section of the receiver the fault is centered.

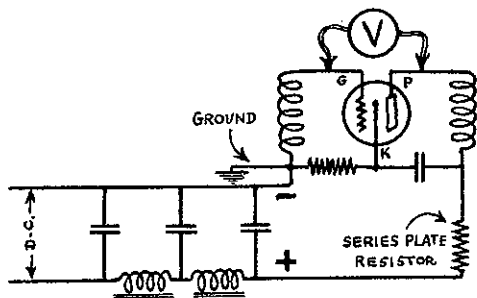


Figure 7

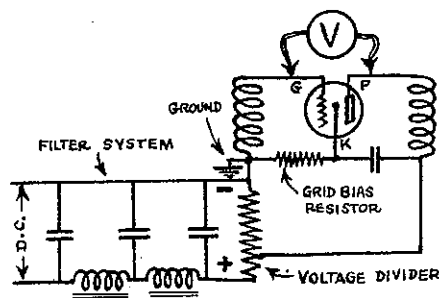


Figure 8

The principles of a test which is often made are shown in Figures 7 and 8. You should trace out these circuits which have been specially drawn to show how the grid and plate of a tube may connect at different points on the power

supply system which includes the voltage divider resistor; the grid in this case being connected to ground, or the negative (-) side, and the plate to the positive (+) side. Hence, if a voltmeter were connected between grid and plate, as shown, the meter would quickly check the cause for lack of voltage on the plate, if this were the trouble, because if no reading were observed the transformer secondary or rectifier would undoubtedly be at fault. Even if the grid bias resistor were open with a circuit arrangement of this kind and the plate circuit were intact you should get a reading. In any event, a reading from grid to plate regardless of its value will suffice to tell us that the continuity of the plate circuit is complete. If a socket of a resistance-coupled amplifier were being analyzed on a grid-to-plate test the grid resistor would be placed in series with your voltmeter and the resistor then would act as a multiplier and the voltage reading obtained would be much less than that of the plate voltage alone, that is, the voltage measured between plate and cathode.

CONTINUITY TESTER OR OPEN CIRCUIT TESTER.

A continuity test circuit consists of a pair of headphones with not less than 4.5 volts in series, or a voltmeter and battery. The arrangement of a continuity test circuit using headphones and battery is shown in Figure 9 and one using a voltmeter and battery is shown in Figure 10. A continuity test itself is used to prove whether a wire circuit, or metallic circuit is open or closed by the indications on the test instrument. If a voltmeter is used it should have a range of sufficient size to give nearly a full scale deflection when connected to the battery terminals. In tests of this kind indication can be

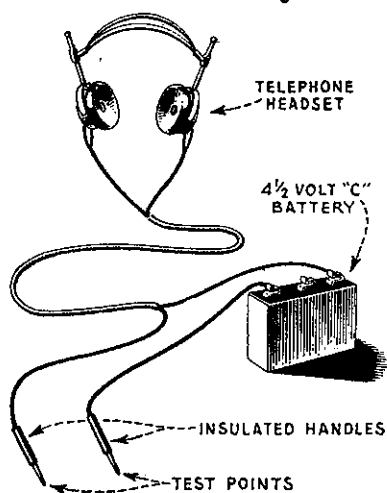


Figure 9

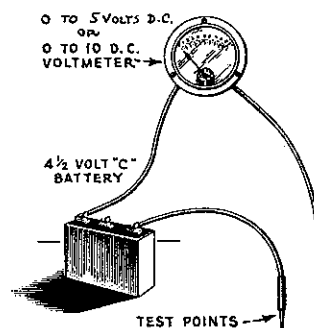


Figure 10

judged more easily by getting as large a movement of the pointer as possible. For example, if a 4.5 volt battery were used the voltmeter should have at least a 0 to 5 volt range. When the test points are touched to the respective ends of a closed or metallic circuit under test, a steady flow of direct current will pass through the circuit and, hence, a click will be heard in the headphones if they are used, or if a voltmeter is used it will give a steady reading. If the circuit being tested has a rather high resistance a low reading on the voltmeter will be observed but if the circuit has a comparatively low resistance a higher reading will be noted. An open circuit will give no indication on the continuity tester since there would be no path furnished through which the direct current might flow. There are many uses to which a test circuit of this kind may be put as have been explained in considerable detail in another lesson on this subject.

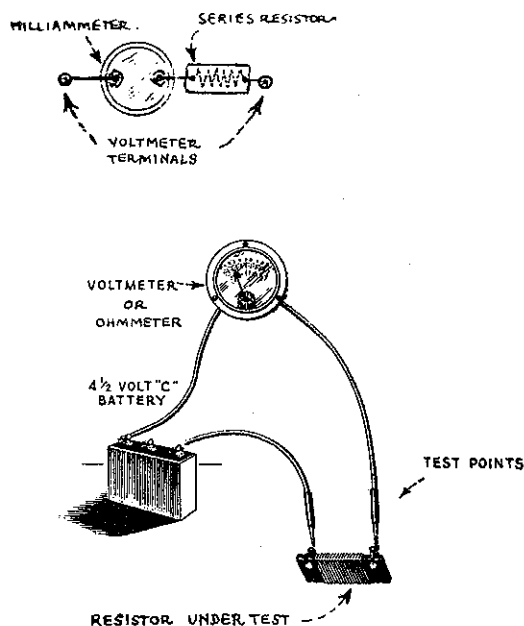


Figure 11



Figure 12

USING A MILLIAMMETER AS A VOLTMETER OR OHMMETER. A milliammeter measures current, a voltmeter measures e.m.f., and an ohmmeter measures resistance values. It is sometimes economical to make one meter do the work of two and even three meters. We have in mind how a milliammeter may be used as a voltmeter by supplying the correct resistance in series with it and how a meter scale if calibrated in "volts" can also be used to read "ohms."

It is only necessary to insert a high resistance, called a "multiplier", in series with a milliammeter to convert it into a voltmeter. Assuming that the meter in the upper sketch (Figure 11) is a milliammeter; it shows how a multiplier would be connected to make it a voltmeter which could be used for a continuity tester. To figure out the size of the multiplier resistance needed for a given milliammeter you can make use of the following formula and substitute values for the letters as follows: The formula is $R = V \div M$. The R stands for the number of ohms of resistance required for the multiplier, which is the unknown quantity in this case; the M is the full scale reading of the milliammeter expressed in the unit ampere, which you get from the meter itself; and the V is the full scale deflection in volts which you must decide upon. If you decide on voltage values which would be even multiples of the values already marked on the milliammeter scale then the scale would not need re-calibrating. This is all explained in the following example. Suppose you select for this purpose a milliammeter with a 0 to 50 m.a. scale, then you could have reading in volts from 0 to 500 volts. Hence, you would know that if the needle moved to the 50 division mark when used to test a circuit the voltage would actually be 500 volts, or if the needle moved half way across the scale, or to the 25 division mark, the voltage would be 250 volts. Any voltage reading indicated on the scale would be multiplied by 10, which is an even multiple, to get the actual voltage.

Now to apply the formula for the milliammeter and voltage scales just suggested, or one in which the 0-50 m.a. range will permit you to read 0-500 volts. Since 50 milliamperes is the equivalent of .05 ampere then M is .05; V is 500;

and R must be equal to $V \div I$, or $500 \div .05 = 10,000$ ohms, the multiplier resistance required. Although voltmeters made up in this way are not intended to take the place of an accurate Wheatstone bridge, for example, yet they are sufficiently accurate for a large amount of ordinary resistance work.

Now to go a step further and explain about the practical conversion of a voltmeter scale to read ohms, that is, to use a voltmeter as an ohmmeter for measuring resistances. A meter of this kind is called a "volt-ohmmeter". For this explanation let us assume that the meter in Figure 11 is a voltmeter with a 0-8 volt scale and it is always used with a 4.5 volt battery to check resistances and, also, assume the voltmeter's resistance to be 1000 ohms per volt; then the ohm scale given below would apply to such a circuit when used to measure resistance values within the limits of the scale. The voltage readings on the 8 volt scale are shown in one column and the corresponding resistance values in the adjoining column. When the test points are touched to the respective ends of a circuit, or resistor under test you get a voltage reading and, therefore, by marking the voltmeter scale of this 0-8 volt voltmeter with the corresponding resistance values and always using the meter with a battery of exactly 4.5 volts you would have an instrument for directly indicating resistances from a few hundred ohms to 100,000 ohms.

Unknown Resistance	Reading on 8 Volt Scale	Unknown Resistance	Reading on 8 Volt Scale
0	4.50	7000	2.40
500	4.23	8000	2.25
1000	4.00	9000	2.11
1500	3.79	10000	2.00
2000	3.60	15000	1.56
2500	3.42	20000	1.28
3000	3.27	30000	0.94
3500	3.13	40000	0.75
4000	3.00	50000	0.62
4500	2.88	75000	0.46
5000	2.77	100000	0.33
6000	3.57		

Figure 11 shows the resistance of a grid bias resistor being measured by means of an ohmmeter; note that it is only necessary to make a series circuit of the meter and its multiplier, the battery and the resistance unit to be measured.

One type of a commercial volt-ohmmeter is shown in Figure 12. It is a combination high resistance voltmeter and a self-contained ohmmeter. This instrument, which is a Jewell model, operates as a d-c voltmeter with three ranges, namely, 0-30-300-600 volts, and as an ohmmeter its ranges are 10,000 and 100,000 ohms full scale, the lower scale being available by means of a push button. The meter gets its voltage supply from a small 4.5 volt battery mounted inside of the case and a compensator is provided for a change in battery voltage. Before using the meter it should be adjusted so that the needle will register on zero ohms which is the last division at the right of the scale, or in the full-scale voltage position with the two "OHM" jacks shorted by a jumper. When the pointer will not deflect to the full scale voltage position or zero ohms, with the "ohms" jacks shorted and the adjustment properly made, the battery has become so weak that it needs replacing with a fresh battery. The resistance to be measured is connected to the two

pin jacks marked "OHMS" through test leads used with the meter. The test leads shown at the right are inserted in the desired pair of pin jacks shown at the top of the meter panel when voltage readings are to be taken.

INCREASING THE RANGE OF VOLTMETERS. While on the subject of meters we will explain a method used to extend the voltage range of a given voltmeter to read higher voltages. We learn from this work that a voltmeter may be considered a straight milliammeter with a resistor connected in series with it as shown in Figure 11 and such a meter would have only two terminal posts.

A method for figuring out the external series resistance necessary to extend the range of a voltmeter follows: First determine the value of the multiple by which it is desired to increase the full-scale reading of the present scale and subtract one from this multiple. The remaining value is then multiplied by the total resistance of the voltmeter to find the external resistance. The total resistance equals the number of ohms per volt multiplied by the top or maximum reading of the present scale. The multiple is determined as follows: If the present range of a voltmeter is 0 to 50 and you wish to increase its range to 0 to 250 the maximum voltage that could be read would be 5 times higher and the multiple would be 5. Or, if a voltmeter's range is 0 to 100 and you desire to extend it to 0 to 1000 volts the multiple in this case would be 10 and so on.

EXAMPLE: Suppose, for the sake of explanation, we have a milliammeter with a range of 0 to 1 milliamperes and suppose it is already provided with a resistor which makes it a voltmeter and suppose the total resistance is 50,000 ohms which includes the resistance of the meter itself and the series resistor, then the range of this voltmeter would be 0 to 50 volts and it would have a resistance of 1000 ohms per volt. Also, suppose you wish to extend the present range of 0 to 50 to 0 to 250. The multiple in this case is 5, from which we subtract 1, thus $5 - 1 = 4$ and 4 is the figure that must be multiplied by the resistance of the meter, or 50,000 ohms, to find the required external resistance; hence $50,000 \times 4 = 200,000$ ohms, the value of the external resistance. Now let us figure the other way around to prove this method. With a voltmeter resistance of 50,000 ohms and an external resistance of 200,000 ohms the total resistance is 250,000 ohms and the voltage required to make the needle move over to full scale deflection (which means that a current of 1 milliamperes or .001 ampere is forced through the circuit) will be $E = I \times R$, or $E = .001 \times 250,000$, or $E = 250$ volts.

It may be both interesting and instructive to many of our students to discuss this subject still further. If a voltmeter's resistance is 1000 ohms per volt (which means that there is a resistance of 1000 ohms for every 1 volt division on the scale) and it has a range of 0 to 8 volts the resistance of the instrument would be 1000×8 , or 8000 ohms. Now apply Ohm's law. If 8 volts were impressed across the terminals of such a voltmeter, or one with 8000 ohms resistance, we know the current flow through both the meter itself and its series resistance would be $I = E \div R$ or $I = 8 \div 8000$ or $I = .001$ amp., or 1 milliamperes. Thus, for this particular meter it takes 1 m.a. to make the needle move to the full scale reading by applying exactly 8 volts to the meter terminals. Now then, if a resistance of unknown value which it was desired to measure by means of this voltmeter were added in series as shown in Figure 11 and the needle only moved half way across the scale you would know that a current of $1/2$ of 1 m.a. (or .0005 amp.) was flowing, or if the needle moved only $1/5$ the distance

across the scale it would indicate a current of $\frac{1}{5}$ of 1 m.a. (or .0002 amp.) and so on. Therefore, knowing that a direct relationship exists between current and resistance according to Ohm's law you could figure out the value of the added resistance, or the resistance under measurement as follows: Assuming that in a test as shown in Figure 11 the needle moved half way across the scale, or to the 4 volt mark since the scale is calibrated from 0 to 8 volts; the current, as just figured out, would be .0005 amp.; and the total resistance or that of the complete circuit would be $R = E \div I$, or $R = 8 \div .0005$, or $R = 16,000$ ohms. But total resistance in this case equals the voltmeter's resistance plus the external resistance under measurement and, therefore, knowing the voltmeter resistance to be 8000 ohms, as we determined at the beginning, we have merely to subtract the voltmeter's resistance from the total resistance to get the value of the unknown resistance, or $16,000 - 8,000 = 8,000$ ohms. Hence, on the half-scale mark we know a resistance of 8,000 ohms is being measured by the voltmeter. Remember that the degree of accuracy of readings obtained on a given meter would depend upon the accuracy of any resistor which you might use in connection with the meter if you attempt to extend its range.

HOW TO CALIBRATE A VOLTMETER SCALE IN OHMS. The principle regarding the relation of volt and ohm readings on the same scale of a meter can be easily understood and figured out by proportion. We will work out an example to explain this point and in doing so we will try to make the arithmetic as simple as possible. There are four quantities involved in a relationship of this kind, three of which you know—they are: (1) the voltmeter's resistance, (2) the full scale voltage reading on the meter scale, and (3) the deflection of the pointer on voltmeter scale when taking a reading. Hence, you can find the remaining or fourth quantity, which is the unknown resistance, by employing a proportion expressed as follows:

Total resistance is to Voltmeter resistance as Full-scale voltage is to Voltage reading

Note that "total resistance" is the sum of the unknown resistance and the voltmeter resistance. In a proportion of this kind the product of the two outside quantities (called the extremes) equals the product of the two inside quantities (called the means).

Now let us assume values for the known quantities and work out the problem. Let the voltmeter's resistance equal 10,000 ohms, the full-scale voltage reading 10 volts, and let us say that when checking a certain resistance the needle deflects to the 4 volt division mark on the scale. Instead of writing "is to" and "as" we will use the symbols : and :: which represent "is to" and "as" in our proportion. Now write the proportion with the known values inserted, thus

$$R(\text{total resistance}) : 10,000 :: 10 : 4$$

Multiplying the "extremes" and the "means" as explained above we get

$$R(\text{total}) \times 4 = 10,000 \times 10$$

$$\text{or} \quad R(\text{total}) \times 4 = 100,000$$

$$\text{or} \quad R(\text{total}) = \frac{100,000}{4}$$

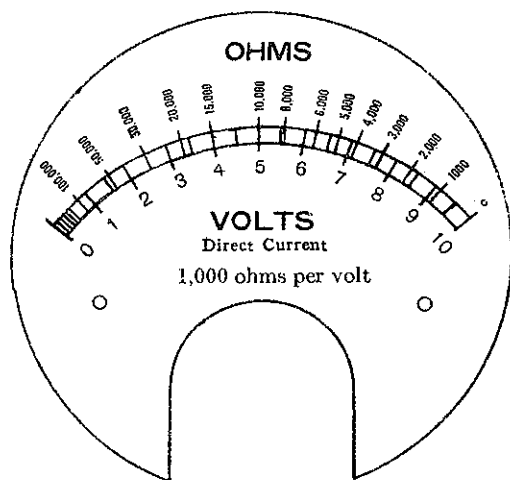
$$\text{Hence,} \quad " = 25,000 \text{ ohms.}$$

Since the total resistance is the combined resistance of the unknown resistance under measurement and the voltmeter's resistance then to find the unknown it is only necessary to subtract the voltmeter's resistance, or 10,000, from the total, or 25,000. Completing this last step in our computation we get

$$R(\text{unknown resistance}) = 25,000 - 10,000, \text{ or } 15,000 \text{ ohms. Ans.}$$

Thus you will notice that 15,000 is marked on the scale opposite the 4 volt division on the same scale shown below in Figure 13. The needle of a voltmeter provided with this scale would indicate 4 volts if an unknown resistance were measured on the voltmeter which has a resistance of 10,000 ohms and a range of 0-10 volts and when the test circuit is operated with an e.m.f. of 10 volts d-c. Any voltage value converted into an ohm value on this scale could be figured out by the same method.

The drawing on this page of a voltmeter scale calibrated in ohms for determining values of unknown resistances should give you a good idea of the relationship between ohms and volts on the same instrument. The meter has a resistance of 1000 ohms per volt and if it is connected to a source of 10 volts d-c when making resistance measurements the unknown resistance readings on the scale will be noted as follows; Using the 10 volt scale the meter's resistance is 10×1000 , or 10,000 ohms, and the unknown resistances will be values given in the first column for corresponding readings that would be observed on the voltage scale given in the second column.



Ohms	Volts
100,000	.91
50,000	1.66
20,000	3.33
15,000	4.00
10,000	5.00
5,000	6.25
2,000	8.35
1,000	9.10

Figure 13

TUBE CHECKER OR TUBE TESTER. This instrument consists of a suitably arranged circuit for supplying operating voltages to different types of vacuum tubes so that they may be roughly checked to determine whether or not they are in good condition. For all-around purposes a tube checker should be capable of testing the condition of practically all the different types of tubes used in receiving sets and it should be easy to place in operation. Therefore, a checker that can be worked from an a-c power line through a power transformer similar to one that is used in a-c sets will be found to be the most advantageous to use for ordinary tube testing.

The diagram of one type of tube checker that operates from any 110 volt, 60 cycle, lighting circuit is shown in Figure 14. This circuit will permit all tubes to be tested, a-c and d-c tubes having filament voltages of 1.5, 2.5, 3.3, 5.0, or 7.5 volts and, also, rectifier tubes of the filament type. Note that when a tube to be tested is placed in a socket it is supplied with filament or heater voltage, as the case may be, from one of the secondaries of the power transformer and the plate voltage is obtained direct from the a-c line with a milliammeter inserted in the plate supply line to measure plate current. The types of tubes that can be tested with this instrument are marked alongside of the socket in which the tube to be tested would be inserted. Refer to Figure 15.

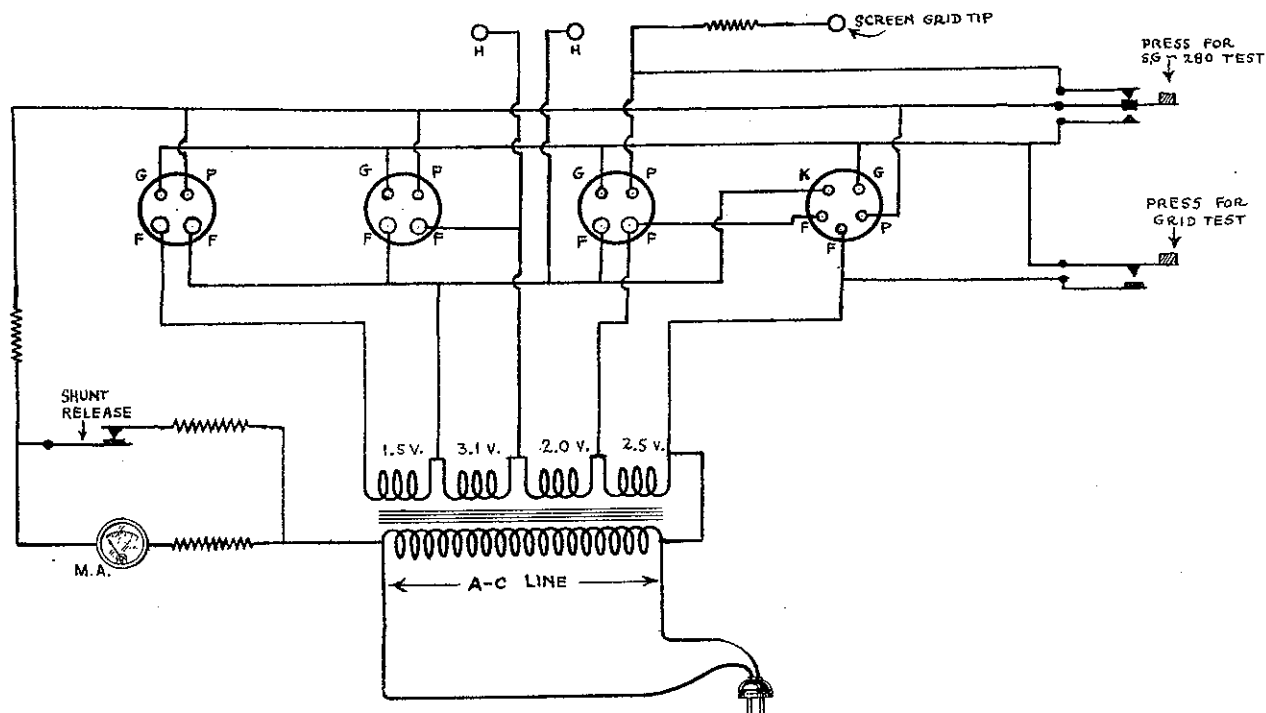


Figure 14

The condition of a tested tube is determined by comparing two meter readings which are taken with the tube operating under different grid voltage conditions and checking the values observed against values which represent average tests taken on thousands of known good tubes tested on that particular kind of a test circuit. The grid test is accomplished by shifting the grid potential from one value to another thereby providing a definite change in plate current; the change in plate current to be expected depends, of course, upon the difference between the two grid potentials. This shift in grid potential can be obtained in different ways. One way is by connecting a 4.5 or 22.5 volt battery in series with the grid of the tube to be tested as we have explained in another lesson on radio servicing where the "grid bias" test circuit is incorporated in the design of a set tester. Another way is by employing a fixed resistor and cutting this "in" and "out" of relation with the grid circuit as would be done when using a checker circuit of the type shown in Figure 16. If you trace out the plate circuit connections coming from either the UX or UY sockets you will see that the plate return side includes the grid resistor marked R1 which may be cut in or out by means of the switch shunted around this resistor. Since a change in grid potential should produce a definite change in plate current, depending on the mutual conductance of the tube, this method provides a very good check on the tube itself. This diagram is given through the courtesy of "Radio".

If a tube checker is provided with a voltage adjuster by means of which you can compensate for variations in line voltage and after once setting the adjustment to the proper position it is only necessary to change the setting when a change in line voltage occurs. To operate the average type checker you have merely to connect the instrument to the voltage supply, insert the tube to be tested in the proper socket and take two plate current readings as explained in the foregoing paragraph. If a tube checker is equipped with

only two sockets for holding receiving tubes then you will find a filament or heater voltage dial provided which should be set at the rated voltage of the tube before inserting the tube in the socket. After these preliminary operations are made and the tube is in the socket it should be allowed to heat for a few moments before taking readings; in testing a heater type tube you would allow more time for the tube to heat than in the case of a filament type. A reading of the plate current passing through the tube should then be read on the milliammeter. This is the first reading. A button, which is usually marked "PRESS FOR GRID TEST", is now pressed and the plate current reading is again noted. This is the second reading. The difference between the two plate readings gives a value which is directly proportional to the mutual conductance of the tube and the greater this difference the better the tube. Certain tube checkers are provided with a two-range milliammeter to accomodate the higher plate current readings of power tubes. The "HIGH RANGE" scale would be used only in cases where the current reading did not come within the limits of the lower scale. See Figure 14.

To check the condition of tubes for ordinary service work it is not necessary that the mutual conductance of the tube be actually measured in micromhos; it is only necessary to know the minimum allowable difference in plate current that should be obtained for a given tube when using the "GRID TEST" where a reading of plate current is read with the test button up and a new reading is taken with it down and comparing the difference or increase in current. Tables or charts which show the comparative values for different types of tubes can only apply to a particular instrument since these values are based on tests made on a large number of tubes which were known to be in good condition. The DayRad tube checker illustrated in Figure 15 has a table of values engraved on its panel and these values are good only for this checker; the table of values classifies the tubes into good, fair, and poor tubes according to the plate current change that is obtained.

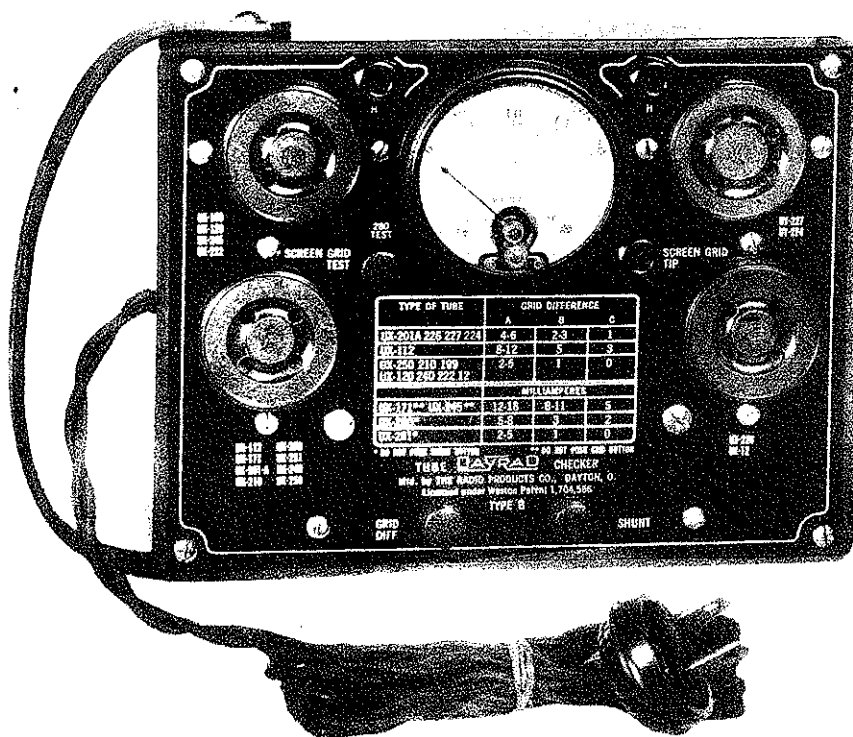


Figure 15

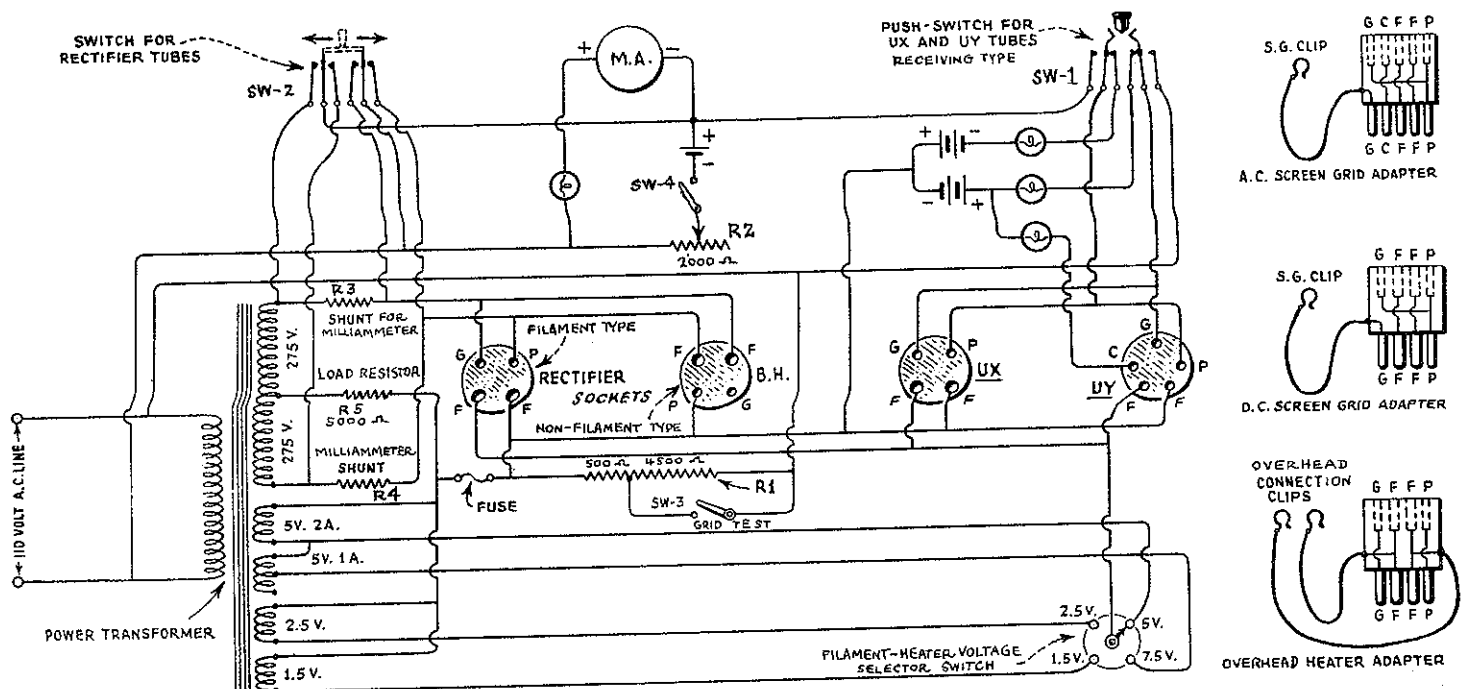


Figure 16

A tube checker of the type shown in Figure 15 will test the condition of practically all the different types of tubes used in receiving sets. It will test amplifier, detector, power and rectifier tubes of the following types; UX-12, 112-A, 120, 171-A, 199, 201-A, 210, 222, 224, 226, 227, 240, 245, 250, 280, 281, Kellogg, Cardon, Pentode, and overhead heater type and the new series 2 volt tubes, 230, 231, and 232. Also, tests are provided for helium non-filament rectifier tubes by operating them under a load. When tests are to be made on screen-grid and overhead heater-filament tubes the extra leads required should be properly connected. The diagram of the tube checker in Figure 14 shows the terminals provided for these leads; the terminals are marked "H" and "H" and "SCREEN-GRID TIP" respectively.

It is to be understood that service tube checkers of the general type described in our lesson give the mutual conductance of tube indirectly in terms of "grid difference" reading. Mutual conductance, you will recall from the definition, is the ratio of the change in plate current to the change in grid potential producing it, under the condition of a fixed or constant plate voltage. A chart is given in Figure 17 to show average test values of good tubes when checked on a Weston tube checker model 555.

Type of Tube	Rated Filament Voltage	READINGS IN MILLIAMPERES		
		Grid Test Button Up	Grid Test Button Down	Minimum Difference
'01-A	5	4.5 to 6.5	8.5 to 11.0	3.5
'99	3.3	2.8 to 5.0	3.5 to 6.0	.8
'00-A	5	1.5 to 3.5	5.0 to 8.0	3.0
'40	5	.5 to 1.5	4.5 to 6.0	2.5
'22	3.3	1.0 to 6.5	7.5 to 10.0	3.5
'26	1.5	5.5 to 9.0	8.5 to 15.0	3.5
'27	2.5	5.0 to 9.0	8.0 to 14.0	3.5
'24	2.5	1.0 to 2.5	4.0 to 7.0	2.5
Power Tubes				
'20	3.3	7.0 to 10.0	8.0 to 12.0	1.0
'12-A	5	2.5 to 3.5	4.0 to 6.0	2.5
'71-A	5	5.0 to 7.5	6.5 to 10.0	1.5
'10	7.5	3.0 to 8.0	10.0 to 14.0	5.0
'50	7.5	1.0 to 5.5	5.5 to 7.5	1.5
'45	2.5	5.0 to 6.0	6.5 to 11.5	1.5
Rectifier Tubes				
'80	5	10 to 15	No Change	
'81	7.5	11 to 15	No Change	

Figure 17

A Method for Protecting the Milliammeter of a Tube Tester. A tube tester should be provided with some sort of protection for its milliammeter to prevent excessive current when testing a tube in which one electrode touches another, that is, when the electrodes are shorted against one another. A common method used to accomplish this purpose is shown in Figure 16 where small flash light bulbs are used in certain positions as shown. There are three bulbs which connect to dry cells and to terminals of the UX and UY sockets and these circuits are controlled by a push-button switch marked SW-1. With the switch in the position shown, or normal position, and with a tube in either socket, one or the other of these bulbs will light if the tube's electrodes are shorted. These circuits are easily traced out and show that the top bulb will light if plate and filament are shorted, the middle bulb will light with a grid-filament short, and the lower bulb will light with a cathode-heater short. The fourth bulb in series with the milliammeter is placed there so that if the variable resistance R2 were lowered too much the voltage of the flash light battery would be impressed on bulb and milliammeter in series. Another method is to connect a standard 10 watt lamp in series with the milliammeter and then shunt a switch across the meter terminals; with a tube in the test socket the switch is opened for a plate current reading only when the lamp does not glow.

Explaining the Operation of a Typical Set Tester. See Figure 16. A regular power transformer, similar to the kind found in a-c receiving sets, is used to supply the necessary plate, filament and heater voltages. The voltage output of the transformer, however, supplies only the plate voltage for a rectifier tube under test, and the plate voltage for a receiving tube which would be inserted in either the UX or UY socket is obtained direct from the a-c line. Hence, when a receiving tube is being tested you get a reading of rectified a-c on the plate milliammeter. A circuit consisting of a variable resistance R2, a flashlight bulb and a 1.5 volt cell is connected in series with the milliammeter to provide a current which bucks or opposes the plate current passing through the meter. So, if you were actually making a tube test with a tube in either the UX or UY socket you would push switch SW-1 to close the plate circuit and the plate current then reading on the meter should be balanced out by adjusting resistance R2 to give a zero reading. During this time switch SW-3 should be closed to give the tube a certain grid bias. The reading that will indicate the condition of the tube is then taken by opening switch SW-3 which places a different potential on the grid and with a good tube in the socket there should be definite change in plate current which is shown by the movement of the needle from zero to some division on the scale. Of course, you would adjust the dial at the lower right to provide the correct filament or heater voltage for the tube under test. The grid bias resistor R1 is so connected from grid to filament that the plate current must flow through it and thus provide the voltage drop which is used to furnish the biasing potential to the grid. Several tubes of different types known to be good would have to be tested on this circuit, as would be the case for any tube tester, to ascertain the plate values to be expected.

When a test is to be made on a rectifier tube it is inserted in the proper socket as marked on the diagram and the circuits are controlled by switch SW-2 which is shown in normal position. With a full-wave rectifier tube in either socket the current through each plate is measured separately by throwing switch SW-2 first to the right and then to the left, the switch being one of the non-locking variety always returns to the normal position shown on the diagram when it is released. To permit the milliammeter to carry the higher currents of rectifier tubes there are two shunt resistors, R3 and R4, so arranged that they connect across the meter terminals when SW-2 is manipulated, and to test a rectifier tube under load conditions a resistor R5 is placed in

series with the center-tap lead of the plate winding of the transformer. The small sketches at the right show three adapters by means of which various types of receiving tubes may be tested; the drawings clearly show how the internal connections from the prongs to the sleeves would be arranged and, also, the connections of the extra clips and leads needed for a-c and d-c screen-grid tubes and top-heater tubes. R3 and R4 are alike; they depend on meter range.

To summarize this section it is seen that similar principles are used in service type tube checkers whereby the worth of a tube is judged by the control exercised by changes in grid potential upon the flow of plate current.

EXAMINATION - LESSON 39

1. Let us assume power is on an a-c set and a socket-analysis test is being made of a full-wave '80 type rectifier tube. (a) Show by a clearly marked diagram where meters would be connected to provide tests with the tube in its socket. (b) Where would meters be connected to provide tests with tube out of its socket?
2. (a) Show in a small sketch where meters could be connected to provide various voltage and current readings in a socket analysis test of a screen-grid tube used in the r-f amplifier stage of a typical a-c set.
(b) Explain the purpose of each meter shown in your sketch and be sure to identify them clearly, using either letters or numbers.
3. Why is it that when testing an a-c set which is in good condition you should obtain a voltage reading between grid and plate of an amplifier tube for example?
4. Using a standard set analyzer how would you test the grid of the detector of an a-c receiver employing grid-leak detection? What reading should be expected when making a grid to cathode test by this means?
5. How would you convert a milliammeter with a range of 0 to 1 milli-ampere into a voltmeter with a range of 0 to 100 volts? Explain fully.
6. (a) Draw the circuit of a continuity tester and name each part.
(b) Explain its general use.
(c) By what other name is it often called?
7. How does an average type tube tester operate to check receiving tubes?
8. If a voltmeter's range is 0 to 150 volts and it has a resistance of 1000 ohms per volt state exactly how this range could be extended to 0 to 450 volts? Show all your work in your answer.
9. State all of the conditions you can think of to explain the different conditions under which a rectifier tube would be tested as compared to a receiving tube when using the set tester in Figure 16.
10. Describe a method by which the milliammeter in a tube tester may be protected against burnout if the electrodes of a tube under test are shorted